THE REQUISITES OF A PURE WATER-SUPPLY.

WILLIAM C. KRAUSS, M. D., F. R. M. S., Buffalo, N. Y.

In the rapid growth characteristic of our American cities and villages, the question of adequate water supply becomes one of the great and pressing needs for early consideration, and in many communities natural or artificial sources are selected more with the view of supplying *quantity* rather than *quality* of water. Even should these sources have been of unquestioned purity the improper disposal of the city's sewage, through the stupidity or carelessness of the proper officials, may have exposed the water to contamination and rendered it in time dangerous and polluted.

Another phase of this question is seen in cities drawing their supply from natural waterways upon which they may be located, in the slowly and gradually decreasing standard of purity, due to the refuse-disposal of rapidly growing cities or villages situated farther toward the source of these same water-courses.

This important and vital question of pure water supply and means of retaining it, is just now attracting timely attention by scientists and engineers, especially in the Middle and Eastern States of our Country. The ravages and immense cost of epidemics through water-borne or water-bred specific germs have awakened many communities to a proper sense of the impending and threatening danger awaiting them, and are devising ways and means to avert the inevitable results.

Just what a pure supply means is hardly open to much debate and may be summed up in five propositions, as follows :

1. That the water-supply of any city or village should

not in any possible way be liable to pollution or contamination from the sewage of any other community.

2. That the sewage of a city should not be emptied into any water course not having a current of three to five miles per hour, and then the sewage entrance should be at a distance one mile or more from the intake.

3. When the water-supply of any city or village is a navigable stream the water should be sand-filtered before pumped into the city reservoirs or water mains.

4. That for ordinary drinking purposes the water should not be taken in its primitive or raw state, but be either filtered, boiled or distilled and aerated.

5. That not only chemical but bacteriological examinations of the water should be made, at least once weekly, to determine its character as a safe or dangerous water for domestic use, and where contamination is shown to exist, the services of an engineer be enlisted to detect, if possible, the cause and origin of such contamination.

This last proposition is the one to which I wish to call the attention of the society today. Who is to decide whether a water is potable, the chemist or the bacteriologist? Up to within a few years ago a chemical examination of water was deemed sufficient to decide its potability, and upon the decree of the chemist the water was either accepted or rejected.

The chemist was generally able to detect the presence of decomposing organic matter, either vegetable, animal, or both, which in his analysis was indicated by the presence of ammonium compounds and the oxygen consuming power of the water. The ammonium compounds, particularly the albuminoid ammonia are usually the result of putrefactive fermentation of nitrogenous matter, and water of high purity should contain from none to .041 parts per million, while in impure water it ranges from .082 and over.

The consumption of oxygen by the water and the formation of carbon dioxide occurs during the fermentation of small quantities of organic matters in the water, and provides a most delicate indication of the presence of such matters in a suspected water. The following proportions are given by Frankland and Tidy, as the basis of interpreting the results of this method :

High organic purity	0.05 parts per million (in three hours).
Medium purity	0.5 to 1.5
Doubtful	1.5 to 2.1
Impure	2.1

The presence of chlorine and phosphoric acid must also be regarded with suspicion when found in large amounts, as they are constant ingredients of animal excretions. Surface waters ordinarily contain but a few parts per million.

The chemist, then, is only able to say that a water contains organic matter in the process of fermentation, but cannot say how virulent or innocent are these destructive agents. It is now generally accepted that organic matters, which by one means or another find their way into surface waters are oxidised and eventually reduced to simple substances by the operations of microörganisms, and not by mere chemical changes independent of them. In other words, the oxidation of impure, polluted water is the result of bacterial activity, and the decree of the bacteriologist is now imperative in deciding the pathogenic or non-pathogenic character of the bacteria.

The number and variety of species present in water from any given source will depend upon conditions relating to the amount of organic pabulum, the temperature, the depth of the water, the fact of its being in motion or at rest, and its pollution from various sources.

The water from artesian wells contains no bacteria, while that of sluggish streams, lakes and rivers receiving the sewage of large cities contains millions of colonies per cubic centimeter. Authorities consider a water having 250 bacteria per cubic centimeter, or less, as entirely safe and usable.

It is now generally recognised that the mere enumeration of the number of colonies which develop from a water under investigation is not a sufficient indication upon which to found an opinion as to its potability. Of course, the greater the number of colonies the more organic pabulum is present for these microörganisms. The bacteriologist is not able as yet to give any definite idea of the amount of such organic matter, while the chemist is able to do so with considerable precision. But the bacteriological examination may prove to be of great value if it succeeds in demonstrating the presence of certain pathogenic bacteria, and in thus preventing the use of a dangerous water. Moreover, the number of colonies is an index of the probable quantity of organic matter which may come from a dangerous source ; and the dangerous pathogenic bacteria are not only likely to be present in such water but they can more readily multiply in it. (Sternberg.) Sternberg gives the number of varieties of non-pathogenic micrococci found in water as thirty, pathogenic micrococci, two—the *Staphylococcus pyogenes aureus* and the *Micrococcus Biskra.* Of the non-pathogenic bacilli seventy-nine varieties have been found, while of the pathogenic bacilli sixteen varieties, including the bacillus of typhoid fever, of cholera, and the *Bacillus coli communis.* These three varieties are the most important findings possible of a bacteriological examination and are positive proof of the presence of alvine dejections in the water.

The continued presence of typhoid fever in a municipality is as inexcusable as vermin in a modern dwelling, and indicates a degree of shiftlessness and apathy not consistent with modern American views and energy.

Lake Erie, the water supply of Buffalo, also of the cities of Toledo, Cleveland, Dunkirk, Erie, Ashtabula, is subject to periodical upheavals, due to its shallowness and the strong west and northwest winds occurring during the winter and spring months. As a result we have roily water five or six months of the year, beginning with November or December and lasting until May or June. It will be interesting, therefore, to compare the results obtained by the city chemist and city bacteriologist, both very capable and scientific gentlemen, and see how they agree or disagree, with a view of determining which is the more trustworthy guide. These examinations are made daily by the bacteriologist and monthly by the chemist, under the direction of the health commissioner :

DECEMBER, 1895.

Chemical Analysis :*

"Organic residue, 3.36 grains per gallon ; albuminoid ammonia, 0.078 parts per million ; oxygen dissolved in four hours, 0 62 parts per million. Conclusion—Water continues in excellent condition."

Bacteriological Examination :

" Highest number of bacteria per cubic centimeter, 765 ; lowest number of bacteria per cubic centimeter, 55 ; average number of bacteria per cubic centimeter, 225 ; in reservoir, 10. The bacillus Janthinus was found on December 18th and 23d, indicating probable filth contamination. Conclusions—Water is in poor condition."

During December large quantities of dead fish were found along the south shore of Lake Erie.

Enteric fever deaths, 11. Death-rate, 11.65 per 1,000.

JANUARY, 1896.

Chemical Analysis, January 28, 1896 :

"Organic residue, 2.72 grains per gallon ; albuminoid ammonia, 0.148 parts per million ; oxygen absorbed in four hours, 0.43 parts per million. Conclusions—This water is in good condition."

Bacteriological Examination :

"Highest number of bacteria per cubic centimeter, 3,250; lowest number of bacteria per cubic centimeter, 195 ; average

* These are taken from the monthly reports of the Board of Health and are the official figures.

number of bacteria per cubic centimeter, 800. Bacillus Janthinus present on January 3d. At that time and during the week following the water was in very poor condition. A gradual improvement is noted."

Death-rate, 11.68 per 1,000. Enteric fever deaths, 5.

FEBRUARY, 1896.

Chemical Analysis, February 28, 1896:

"Organic residue, 1.96 grains per gallon; albuminoid ammonia, .092 parts per million; oxygen dissolved in four hours, 0.56 parts per million. Conclusions—Water is good."

Bacteriological Examination:

"Highest number of bacteria per cubic centimeter, 8,820; lowest number of bacteria per cubic centimeter, 60; average number of bacteria per cubic centimeter, 1,000. Tap water figures excessive, due to storms, dirty ice and low water in reservoir."

Death-rate, 10.61 per 1,000. Enteric fever deaths, 3.

MARCH, 1896.

Chemical Analysis, March 28, 1896:

"Organic residue, 3.31 grains per gallon; albuminoid ammonia, 0.077 parts per million; oxygen absorbed in four hours, 0.510 parts per million. Conclusions—This water is in excellent condition."

Bacteriological Examination:

"Highest number of bacteria per cubic centimeter, 990; lowest number of bacteria per cubic centimeter, 65; average number of bacteria per cubic centimeter, 260. In the reservoir there were found, on March 2d, 2,205, and on March 13th, 19,790 bacteria per cubic centimeter, due to slush. Conclusions—The condition of the water is good."

Death-rate, 11.58 per 1,000. Enteric fever deaths, 4.

APRIL, 1896.

Chemical Analysis, April 28, 1896:

"Organic residue, 2.67 grains per gallon; albuminoid ammonia, 0.032 parts per million ; oxygen absorbed in four hours, 0.302 parts per million. Conclusions—This water is in excellent condition."

Bacteriological Examination :

"Highest number of bacteria per cubic centimeter, 20,160; lowest number of bacteria per cubic centimeter, 80 ; average number of bacteria per cubic centimeter, 3,000. Conclusions—Large bacterial contents during this month, due to quantities of dirty ice. The water is not in good condition, but no harmful or polluted water organisms have been found."

Death-rate, 12.67 per 1,000. Enteric fever deaths, 4.

MAY, 1896.

Chemical Analysis, May 28, 1896 :

"Organic residue, 3.24 grains per gallon ; albuminoid ammonia, 0.088 parts per million ; oxygen absorbed in four hours, 0.55 parts per million. Conclusions—This water is in poorer condition than last month. There is evidence of contamination."

Bacteriological Examination:

"Highest number of bacteria per cubic centimeter, 18,900; lowest number of bacteria per cubic centimeter, 230 ; average number of bacteria per cubic centimeter, 2,300. Conclusions—Ice stopped running on May 7th, after which time the bacterial contents gradually lowered until the 14th. On this date and the day following the number increased, due to wind. At present time (May 26th) water is in good condition (270 per cubic centimeter)."

Death-rate, 11.40. Enteric fever deaths, 1.

JUNE, 1896.

Chemical Analysis, June 29, 1896 :

"Organic residue, 3.97 grains per gallon ; albuminoid ammonia, 0.087 parts per million ; oxygen absorbed in four hours, 0.659 parts per million. Conclusions—This water has improved somewhat in quality since the last examination."

Bacteriological Examination:

"Highest number of bacteria per cubic centimeter, 700; lowest number of bacteria per cubic centimeter, 35; average number of bacteria per cubic centimeter, 235. Conclusions —The water is in good condition."

Death-rate, 11.79 per 1,000. Enteric fever deaths, 3.

During December, although the organic matter in the water was small and the number of bacteria correspondingly so, yet there was found a bacillus which is generally found in water which has undergone sewage contamination. During this month there were eleven deaths reported from typhoid fever. The bacillus of typhoid was not found in the water, although repeated examinations were made with this end in view. It is, however, extremely difficult to detect the typhoid bacillus, as the following extract, quoted from Rafter* will prove:

"Messrs. Laws and Andrewes† state that working on ordinary London sewage they failed in every case to recognise the typhoid bacillus, until finally the failures were so numerous that they became oppressed by a sense of mathematical improbability. Thus the average amount of sewage produced in London amounts to 200,000,000 gallons per day. During June, 1894, while the investigation was in progress, 177 cases of typhoid fever were notified in London, to which may be added thirteen cases of continued fever, making 190 cases in all. Adding something for cases not reported and Messrs. Laws and Andrewes conclude that during June, when typhoid is by no means prevalent, it may be assumed that there were 200 cases in all. Some of these suffer from constipation and hence contribute very little fecal matter to the general mass of sewage. For these and other reasons cited, any estimate

* George W. Rafter, on Lake Erie as a Water Supply, *Buffalo Medical Journal*, August, 1896.

† Report on the Result of Investigation on the Microörganisms of Sewage. By J. Parry Laws and F. W. Andrewes, 1895.

of the average amount of sewage contributed daily by typhoid cases in London must be purely conjectural, but at a reasonable estimate it is placed at two hundred and fifty millionths of the whole, and, as Laws and Andrewes point out, every endeavor is made to disinfect this before it is allowed to pass into the sewers. The mathematical chances of detecting the typhoid bacillus in ordinary London sewage are, therefore, extremely remote. Assuming the typhoid bacillus to be intimately mixed with the ordinary sewage there would be only one typhoid bacillus in one-tenth of a cubic centimeter of sewage at the outfalls.

"But the investigators only found it possible to work on one five-thousandths of a cubic centimeter, and this only when 90 per cent. of the organisms were inhibited by the addition of 0.05 per cent. carbolic acid and incubation at 37° Cent.

"These considerations were so discouraging that it was determined to work on sewage from a fever hospital, and arrangements were accordingly made to allow the dejections from forty patients in the Eastern Hospital, at Homerton, to pass into the hospital sewer for two days without disinfection. A series of samples were then taken and cultivations made therefrom at once. Without going further into detail, it may be stated that from the whole series of sewage taken under these circumstances only two colonies of the bacillus of typhoid fever were certainly differentiated. In their summation Messrs. Laws and Andrewes say:

"'We must be content to have shown that in the drain from the typhoid block of a fever hospital, when the stools had not been disinfected for two days, a bacillus can be found which, so far as demonstration can go, is identical with that believed to be the actual cause of typhoid fever. So far as we are aware, this important fact has never been previously demonstrated.'"

In January, according to the city chemist, the water was in good condition, while the bacteriologist again found the bacillus Janthinus and reported the water to be in "very poor condition" for the first half of the month and a gradual improvement the last half. The number of typhoid deaths decreased to five. In February and March both officials found the water in good condition, also evidenced by the death-rate and the typhoid deaths, three and four respectively.

For the months of April and May there exists a disparity between the two reports, the chemist claiming that the water was in "excellent condition" during May, while the bacteriologist found the water "not in good condition," because of large bacterial contents. The deaths from typhoid fever were four—an unusal time for typhoid to be present. For May the chemist found evidences of contamination, while the bacteriologist, on the preceding day, considered the water in good condition, containing on that day only 270 bacteria per cubic centimeter. In June both officers found the water in good condition.

Reviewing the opinions of the city chemist and the city bacteriologist, it is evident that the disparity occurs whenever the water is in an improper and unhealthy condition, and, when such is the case, it is only fair to assume that some error has been committed favoring the water.

The bacteriological examination as well as the chemical analysis are, therefore, alike necessary in demonstrating the purity and safety of a drinking water, and neither should be omitted when the least suspicion exists as to its contamination. The consumers should be immediately warned of the dangers of using such water in its raw state, and should be enjoined upon to make some attempt at purification, either filtering, boiling or condensing. This applies not only to those cities whose water-supply is open to contamination but to every city having a public supply.

Besides the chemist and bacteriologist, the water department of every city, whose supply is liable to contamination, should have the services of an engineer, whose fame does not rest upon his theoretical knowledge and bureaucratic propensities, but upon his practical information of the laws of hydrology and hydrodynamics. Such an one, well versed in the hydrography of his locality, could almost prognose the condition of his water-supply and be an important aid to the city's health department. As such he would be able to render the same valuable services, as does the Local Forecaster in meteorology, and give warning several days beforehand of marked changes in the quality of the water.

While the chemist and bacteriologist are only able to detect impurities after contamination, the engineer could foresee these changes and give sufficient warning, or attempt to overcome the impending contamination before the city mains and reservoir are filled with the poisonous liquid.

The question of food contamination and adulteration has attracted the attention of the lowest tribunal up to the highest (Filled-cheese bill of last Congress), and severe laws are upon the statute book punishing offenders, and yet the water-supplies of some of our cities are openly and flagrantly polluted and no attempt whatever is made at punishment, partly because insufficient attention has been given to this most important subject. The time, however, may not be far distant when the same rigid inspection and the same jealous care will be extended to one of the most important adjuncts to the life, health and comfort of every individual, of every society and of every commonwealth.